INFLUENCE OF RICE CROP ESTABLISHMENT METHODS, IRRIGATION AND PHOSPHORUS LEVELS ON PRODUCTIVITY, NUTRIENT UPTAKE AND SOIL PROPERTIES OF ZERO-TILL MAIZE (*ZEA MAYS* L.) IN RICE BASED CROPPING SEQUENCE

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Abstract: A field experiment was conducted on sandy clay loam soils at Agricultural College Farm, Hyderabad, during *kharif* and *rabi* seasons of 2007-08 and 2008-09 to study the effect of two rice crop establishment methods (Transplanted and aerobic) as main-plot treatments and combination of two irrigation (IW: CPE ratio of 0.8 and 1.0) and four phosphorus levels (0, 13.2, 26.4 and 39.6 kg P ha^{-1}) as sub-plot treatments in a split-plot design with replicated four times on yield, nutrient uptake and soil physico-chemical properties of rice- sequential zero-till maize cropping system. The mean rice yield was highest under transplanted method (5.58 t ha^{-1}) compared to aerobic method (4.49 t ha^{-1}) of rice establishment due to significant improvement in all the ancillary characters of growth and yield attributes. Whereas, the mean productivity of zero-tillage maize was highest when grown after aerobic rice method (6.67 t ha^{-1}) as compared to transplanted method (6.34 t ha^{-1}) resulted in higher nutrient (N, P and K) uptake .There was significant improvement in all the growth and yield attributes of maize with irrigation scheduled at IW: CPE ratio of 1.0 as compared to IW: CPE ratio of 0.8 in zero -tillage maize. The grain yield with application of 26.2 kg P ha^{-1} proved significantly superior to 13.2 kg P ha^{-1} and control (0 kg P ha^{-1}) and was comparable with that of 39.6 kg P ha^{-1} in zero-tillage maize. The higher level of phosphorus maintained the superiority in recording higher growth and yield. The soil physical properties (soil penetration resistance, bulk density, and mean diameter of aggregates) improved when rice was grown under aerobic method of rice cultivation followed by maize.

Keywords: Irrigation and phosphorus levels, rice crop establishment methods, productivity, nutrient uptake and soil properties, rice -zero-till maize cropping sequence.

Introduction: Rice-maize is one of the pre-dominant cropping system of both command and non-command areas of Andhra Pradesh. Shortage of irrigation water and increased cost of transplanting in rice made several researchers to study the possibility of rice cultivation under irrigated dry conditions (aerobic). The results are encouraging with aerobic rice method of cultivation where in the productivity levels were ranging from 4.5 to 5.0 t ha^{-1} with significant saving of irrigation water and enhanced water productivity. Of late, maize is finding place after *kharif* rice under zero-tilled conditions while replacing the traditional pulse crops due to yield decline caused by salinity, weed infestation, pests and diseases. Irrigation as well as nutritional requirements, particularly, the phosphorus nutrition of zero-tilled maize is different from conventionally sown maize with due land preparation because of alteration of both physico-chemical properties of soil under rice-based situations (Mahapatra and Behera, 2004). The effect of crop establishment methods of rice significantly influenced the nutrient uptake and soil physical properties after the two crop cycles in rice as well as the subsequent zero-tillage maize. Hence present study was undertaken to evaluate rice-zero till maize cropping sequence in terms of productivity, nutrient uptake and soil physico–chemical properties.

Material and Methods: The field study was conducted during *rainy* and *winter* seasons of 2007-08 and 2008-09 at Water Technology Centre, College Farm (17^{o} 19' N latitude and 78^{o} 23' E longitude, 542.6 m above mean sea level), College of Agriculture, Rajendranagar, Hyderabad [According to Troll's climatic classification, it falls under semi-arid tropics (SAT) and characterized by hot summer and cold winters]. The mean maximum and minimum temperatures ranges from 31.2^{o}C and 15.6^{o}C in 2007-08 and 32.1^{o}C and17.0 ^{o}C in 2008-09 and with an average annual rainfall of 398.5 mm and 1095.6 in 2007-08 and 2008-09 which was received in 38 and 39 rainy days, respectively. The experimental soil was sandy clay loam with pH 7.4, low in organic carbon (0.51%) and available nitrogen (240.6 kg ha^{-1}), medium in available phosphorus (15.39 kg ha^{-1}) and high in available potassium (631.6 kg ha^{-1}). The experiment was conducted in split-plot design with four replications. During *rainy (kharif)* season, the two methods of rice crop establishment (Transplanted and aerobic method) were evaluated where in during *winter* season zero-tillage maize was grown in sequence to rice while considering the two previous rice crop establishment methods as main-plot treatments and combination of two levels of irrigation (1.0 and 0.8 IW: CPE) and four levels of phosphorus (0, 13.2, 26.4 and 39.6 kg P ha^{-1}) as sub-plot treatments. During *rainy* season a thirty day old seedlings (three/hill) of semi dwarf rice variety '*Cottondora sannalu*' (MTU 1010) were transplanted at a spacing of 20x 15 cm in a puddled field. Whereas under aerobic method, direct seeding of dry seed was sown in solid rows at a row spacing of 20 cm at the same date when nursery sowing was done for transplanted rice and adopted the recommended package practices,

For transplanted rice, at each irrigation 2 cm up to P.I stage and later 5 cm of standing water level was maintained. Whereas for aerobic rice initially, one soaking irrigation was given. One week after germination, the irrigations were scheduled. When the soil moisture reaches to around 28% which is equivalent to 0.2 bar or -20 Kpa, 50 mm of irrigation water was given. The soil moisture tension is measured with theta probe soil moisture sensor ML2. As the experimental site is sandy clay loam soil, the soil moisture tension of -20 Kpa generally reaches within 4 days. For both methods at each irrigation the amount of water applied was measured and directly delivered in to the plot through water meter attached to the water source by fixing it to a hose pipe and shifting it from plot to plot.

During *winter* (*rabi)* season, paraquat 50 EC (non-selective herbicide) @ 1.25 kg ha^{-1} was sprayed immediately after rice harvest to control the existing weeds as well as to arrest the re growth of rice stubbles. Maize hybrid 'DHM 117' seeds were dibbled at a spacing of 60x 20 cm under zero-tillage condition. One day after sowing, atrazine a pre-emergence herbicide was sprayed @1.0 kg ha^{-1}. A recommended dose of N and K fertilizers were applied @ 120 N and 40 K kg ha^{-1} and P fertilizer was applied as per the treatments imposed. The entire phosphorus and potash was applied as basal in the form of single super phosphate and muriate of potash and N was applied in three splits (1/3 as basal, 1/3 at knee high and 1/3 at tasseling & silking) in the form of urea. Pests and disease control were adopted as per the recommendations for the region. One pre-sowing irrigation followed by one common irrigation each of 25 mm immediately after sowing of the crop was given to ensure uniform germination. Subsequent irrigations were scheduled based on IW: CPE ratio. In IW: CPE approach, 50 mm depth of irrigation water was applied uniformly when cumulative pan evaporation (CPE) reached the level of 62.5 and 50 mm in order to get IW: CPE ratio of 0.8 and 1.0, respectively. By multiplying the depth of irrigation (50 mm) and area of the plot, volume of irrigation water required for each plot was arrived. Calculated volume of water was delivered to respective plots through the water meter attached to the water source by fixing it to a hose pipe and shifting it from plot to plot. The Cumulative Pan Evaporation values were obtained from standard USWB Class A pan. Plant samples were analyzed for the N, P and K contents. Total uptake of nutrients were computed by multiplying the per cent nutrient content with dry matter. Prior to the sowing and immediately after harvest of maize crop, some of the physical characteristic *viz*., bulk density, soil penetration resistance, mean weight diameter (MWD) of maize crop were assessed by adopting standard procedures. The paired T-test was employed for comparing the two systems of rice during *kharif* season and maize in *rabi* season laid out under split plot design and analysed the data by applying factorial analysis of variance as outlined by Panse and Sukhatme (1985).

Results and Discussion:

Effect of rice crop establishment methods on productivity and nutrient uptake of rice –zero-till maize: During rainy season the mean rice yield was highest under transplanted method of establishment (5.58 t ha^{-1}) compared to aerobic method (4.49 t ha^{-1}) of rice establishment (Table 1). The higher grain yield might be due to efficient utilization of water and nutrients under puddle condition of transplanted method. Moreover, the higher yields in transplanted method may be due to no lodging and beneficial effect on ancillary characters such as tiller number m^{-2}, number of panicles m^{-2}, filled grains panicle^{-1}, grain weight panicle^{-1} and test weight and low yield in aerobic rice may be due to excessive vegetative growth and more panicle density caused tillering mortality and spike let sterility than the transplanted rice. Similar results are also reported by Gill *et al*. (2006).

In winter season the mean maize productivity was highest when grown after aerobic rice method (6.67 t ha^{-1}) as compared to transplanted method (6.34 t ha^{-1}) under zero-tilled conditions (Table 3). Similarly, the maize yield attributes (cob number ha^{-1}, cob weight, cob length, cob girth, number of grains cob^{-1} and shelling percentage were significantly higher when grown after aerobic rice method compared to transplanted method. The favorable conditions under aerobic rice cultivation might improved the plant growth and dry matter and also crop with optimum source-sink ratio facilitate proper portioning of photo synthetates and thus resulted in better filling of grains (Table 2). In case of transplanted method of establishment, due to puddling soil structural changes along with formation of hard pan development in sub-soil might have restricted the root growth which in turn reduced shoot growth. Where in, aerobic rice establishment the dry land preparation was done and good pulverized soil condition facilitated for better root development and good crop performance. These results are supported by Gangwar *et al*. (2008).

The nutrient uptake studies in zero-tillage maize revealed that significantly more up take of N, P and K was associated with the crop grown after aerobic rice (Table 4). The pattern of N, P and K uptake was in accordance with the pattern of dry matter production and improved uptake increased the yield. The nutrient status of soil after harvest of maize indicated that soil available N, P and K was found significantly more under aerobic rice system as compared to transplanted system. The aerobic condition of soil encouraged mineralization of soil nutrients because of more activity of microbes, thus the status of soil available nutrient was enhanced.

The comprehensive study of nutrient uptake and nutrient status after two cycles of rice-maize system revealed that soil available N and K decreased respectively in comparison to initial soil N and K status. However, in contrast, the phosphorus application resulted in substantial build up of soil phosphorus at higher doses of 26.4 and 39.6 kg P ha^{-1}.

Effect of irrigation and phosphorus levels on productivity and nutrient uptake of zero-tillage maize: The irrigations scheduled at IW: CPE ratio of 1.0 resulted in overall improvement in plant growth and development and yield attributes and finally the grain yield of zero-tillage maize over that of 0.8 IW: CPE ratio.(Table 2). There was a mean grain yield advantage of 490 kg was observed with higher frequency of irrigations scheduled at IW: CPE ratio of 1.0 as compared to IW: CPE ratio of 0.8. Similar response in case of stover yield was also observed.

Adequate supply of moisture under IW: CPE ratio of 1.0 helped in better utilization of both soil and applied nutrients thus improved growth and yield attributes. Moreover, the soil of experimental site was sandy clay loam in texture whose moisture retentive capacity is relatively poor, therefore to meet the vigorously growing crop demand, frequent irrigations given under 1.0 IW:CPE were congenial for better growth and yield compared to 0.8 IW:CPE ratio Theses results were supported with the findings of Manish Kumar *et al.(* 2001) and Gourangakar and Harsha (2005).

There was a mean increase in grain yield of 2070 kg with the application of 26.4 kg P ha^{-1} over the control (0 Kg P ha^{-1}). Significant difference in yield was also observed between 13.2 and 26.4 kg P ha^{-1} and there was marginal increase in yield beyond 26.4 kg P ha^{-1}. Application 26.4 kg P ha^{-1} significantly increased the total cob number ha^{-1}, cob length, cob girth, individual cob weight and shelling percentage (Table 3). The significant increased yield and yield attributes with increased levels of phosphorus application was also reported by Ahmad Alias *et al.* 2003; Gill *et al.* 2006 and Iqbal Hafiz, 2003.

The influence of phosphorus was more pronounced at higher irrigation levels (IW: CPE ratio of 1.0) on yield attributes and final grain production. Higher irrigation frequency (IW: CPE ratio of 1.0), increase in level of phosphorus up to 26.4 kg P ha^{-1} resulted in increased yield attributes. It has been reported that zero- tillage increased total P in the surface 10 cm soil by 15% compared to conventional tillage which was mainly due to adequate availability of soil moisture in the zero-tillage conditions for a prolonged period (Selles *et al.*1997). The higher level of phosphorus application improved the mean diameter of the aggregates under aerobic method which improves aeration and leading to better root and shoot growth of maize compared to transplanted method.

The adequate water supply in the plots through irrigation provided at 1.0 IW:CPE resulted in significantly higher N,P and K uptake over that of irrigations at 0.8 IW: CPE ratio. Increasing level of phosphorus from 0 to 13.2 and 26.4 kg P ha^{-1} significantly increased the N, P and K uptake and was comparable over that with 39.6 kg P ha^{-1}(Table 4) . The adequate water supply at 1.0 IW: CPE ratio might have increased the availability of soil nutrients which enhanced the nutrient recovery and their use efficiency by maize crop. The greater availability of soil moisture favoured for greater phosphorus supply to the crop under zero-tilled conditions and also the response to applied phosphorus was more because the native soil contribution was low due to less mineralization under zero-tillage conditions. These observations are in agreement with those of Selles *et al.* (1997).

Effect of rice crop establishment methods, irrigation and phosphorus levels on soil properties of rice- zero-tillage maize: Regardless of the crop establishment methods, after the 2nd year of the study, soil pH, EC, OC, and BD were higher as compared to that after1st year. Among the two rice crop establishment methods, transplanted method of establishment recorded higher values of soil pH, EC and BD. However, the soil organic carbon was almost similar under both methods of establishment (Table 5). The soil penetration resistance (SPR) at the time of harvest of maize was comparatively reduced as compared to that at the time of sowing (Table 6). Among the two methods of rice establishment, maize grown in aerobic method of establishment recorded less SPR compared to puddled transplanted method.The other physical characters like soil pH and EC values were comparable under transplanted method of establishment and aerobic method of establishment. The organic carbon and mean weight diameter of aggregates were higher under aerobic method whereas, bulk density higher under transplanted method which provides better aeration and there by increased plant growth.

With regards to irrigation levels lower values of soil penetration resistance, soil pH and EC were recorded when irrigation was scheduled at 1.0 IW:CPE ratio compared to 0.8 IW:CPE, whereas, the OC (%), B.D and MWD were less under 0.8 IW:CPE treatment compared to 1.0 IW:CPE treatment. All the physical characteristics were recorded higher at 26.4 kg P ha^{-1} and comparable with that of 39.6 kg P ha^{-1}(Table 5).

Conclusions and Recommendations: In zero-till system, the residues of previous crop and it's soil health status have immediate impact on the sequential crop. After the harvest of sequential crop the final health status of the soil has bearing on the sustainability of the cropping system for posterity. From the present study, it can be concluded that transplanted method of rice establishment was productive, profitable in terms of grain yield, net returns and benefit: cost ratio compared to aerobic method of establishment. Whereas the aerobic method of rice cultivation was found advantageous in terms of low water use and higher water productivity. Further, the zero-tilled maize grown in sequence to aerobic rice was proved superior in obtaining higher grain yield and nutrient use and is maintained desired soil physical and physico-chemical properties as compared to that grown after transplanted rice. In the irrigated command areas the aerobic rice-maize system would be a viable option compared to the transplanted rice-maize system in terms of water saving and sustainability

Table 1: Influence of rice crop establishment methods on yield attributes and grain yield of rice (Pooled data 2007 and 2008)

Treatment	Panicles m^{-2}	Panicle length (cm)	Panicle weight (g)	Spikelets $panicle^{-1}$	Filled spikelets $panicle^{-1}$	Spikelet sterility (%)	1000 grain weight (g)	Grain yield (t ha^{-1})
Transplated rice	279	19.9	2.6	99.2	86.4	11.2	20.3	5.58
Aerobic rice	263	18.3	1.9	88.1	79.5	16.6	19.2	4.49
CD(P=0.05)	17	0.88	0.17	6.56	5.14	2.49	0.65	425

2: Influence of rice crop establishment methods, irrigation and phosphorus levels on growth parameters of zero-tillage maize (Pooled data 2007-08 and 2008-09)

Treatments	Plant height (cm)	Dry matter (t ha^{-1})	LAI	Days to 50% silking	Days to 50% maturity	Root mass density (g cm^{-3}) at 50% flowering	Root mass density (g cm^{-3}) at harvest
Main-plots: Crop establishment methods							
Transplanted rice	181.5	13.23	2.89	67.39	103.59	3.08	2.68
Aerobic rice	199.9	15.22	3.07	66.7	102.11	3.29	3.07
SEm ±	1.36	2.74	0.02	2.39	0.22	0.07	0.09
CD(P=0.05)	3.96	7.52	0.06	NS	0.71	0.15	0.18
Sub-plots							
Irrigation levels (IW:CPE ratio)							
0.8	186.4	13.51	2.82	65.99	98.47	3.03	2.69
1.0	198.9	14.94	3.14	68.11	106.78	3.34	3.06
SEm ±	1.86	2.89	0.07	0.25	0.44	0.14	0.09
CD(P=0.05)	3.83	7.26	0.15	0.51	0.89	0.29	0.19
Phosphorus levels P kg ha^{-1}							
0	171.2	9.55	2.68	64.38	96.94	2.41	2.19
13.2	183.8	14.08	2.91	67.44	106.78	3.00	2.60
26.4	197.5	16.40	3.10	68.13	106.00	3.63	3.30
39.6	210.5	16.87	3.24	68.25	107.37	3.71	3.42
SEm ±	2.04	3.48	0.09	0.31	0.63	0.16	0.14
CD(P=0.05)	4.12	8.16	0.19	0.72	1.26	0.35	0.29

Table 3: Influence of rice crop establishment methods, irrigation and phosphorus levels on yield parameters and yield of zero-tillage maize (Pooled data of 2007-08 and 2008-09)

Treatments	Cob Number ('000 ha)	Cob Weight (g)	Cob length (cm)	Cob girth (cm)	Grains cob^{-1}	Shelling percentage (%)	Grain yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)
Main-plots: Crop establishment methods								
Transplanted rice	55.1	208.3	17.58	13.68	393	69.3	6.34	8.03
Aerobic rice	57.4	214.4	18.68	13.79	409	70.9	6.67	8.39
SEm ±	0.32	2.88	0.12	0.05	2.12	0.40	0.06	0.09
CD(P=0.05)	0.74	5.92	0.24	0.11	4.76	0.84	0.18	0.29
Sub-plots: Irrigation levels (IW:CPE ratio)								
0.8	55.4	205.5	17.65	13.47	395	69.3	6.26	7.99
1.0	57.1	217.1	18.61	13.98	405	70.9	6.75	8.44
SEm ±	0.43	2.71	0.15	0.16	1.93	0.42	0.09	0.09
CD(P=0.05)	0.89	5.46	0.30	0.32	3.88	0.88	0.19	0.19
Phosphorus levels kg P ha^{-1}								
0	49.9	132.4	16.50	12.73	344	64.8	5.14	6.52
13.2	54.6	228.2	17.99	13.64	403	69.4	6.37	8.18
26.4	59.3	240.3	18.93	14.24	426	72.7	7.21	9.04
39.6	61.2	244.3	19.07	14.32	430	73.3	7.31	9.12
SEm ±	0.62	3.83	0.19	0.23	2.73	0.62	0.12	0.13
CD(P=0.05)	1.25	7.72	0.39	0.39	5.50	1.29	0.26	0.27

4: Influence of rice crop establishment methods, irrigation and phosphorus levels on Nutrient uptake and post harvest nutrient available status of zero-tillage maize

	Nutrient Uptake (Kg ha^{-1})			Available soil nutrients (Kg ha^{-1})		
Treatments	N	P	K	N	P	K
Main-plots: Crop establishment methods (M)						
Transplanted rice	111.90	17.63	99.75	219.66	20.39	549.60
Aerobic rice	110.43	18.19	104.67	226.94	21.91	560.16
SEm±	1.35	0.27	1.00	1.69	0.32	3.54
CD(P=0.05)	2.88	0.57	2.09	3.55	0.70	7.81
Sub-plots: Irrigation levels (IW: CPE ratio)						
0.8	104.34	16.05	94.85	220.95	21.18	547.06
1.0	117.99	18.87	109.57	225.66	22.09	562.95
SEm±	1.51	0.38	2.79	1.91	0.29	3.77
CD(P=0.05)	3.08	0.79	5.87	3.93	0.59	8.12
Phosphorus levels kg P ha^{-1}						
0	76.29	9.59	72.15	203.64	15.77	492.1
13.2	16.34	16.69	94.79	217.97	20.61	558.35
26.4	128.98	22.11	117.93	231.84	23.01	576.89
39.6	133.04	23.26	123.96	239.78	25.2	592.19
SEm±	3.12	1.24	3.24	3.74	0.71	7.25
CD(P=0.05)	6.56	2.75	7.11	8.23	1.52	15.13

Table 5: Effect of crop establishment methods, irrigation and phosphorus levels on physical and physico-chemical properties of soil after harvest of maize (Mean of two years)

Treatments	Soil penetration resistance (SPR) (kg cm⁻²)	Soil pH	Electrical conductivity (dSm⁻¹)	Organic carbon (%)	Bulk density (Mg m⁻³)	Mean weight diameter(MWD) (mm) > 0.25 mm
Main-plots: Crop establishment methods (M)						
Transplanted rice	45.8	7.61	0.38	0.63	1.50	1.75
Aerobic rice	41.7	7.55	0.36	0.67	1.46	1.79
SEm ±	1.09	0.04	0.01	0.02	0.03	0.02
CD(P=0.05)	2.46	NS	NS	0.04	0.06	0.04
Sub-plots:Irrigation levels (IW: CPE ratio)						
0.8	44.7	7.59	0.38	.063	1.46	1.75
1.0	43.6	7.56	0.36	0.66	1.49	1.80
SEm ±	0.06	0.09	0.02	0.03	0.03	
CD(P=0.05)	NS	NS	NS	0.06	0.02	0.04
Phosphorus levels kg P ha⁻¹						
0	46.5	7.53	0.35	0.60	1.46	1.69
13.2	44.6	7.58	0.36	0.63	1.48	1.73
26.4	43.1	7.61	0.37	0.67	1.49	1.78
39.6	42.4	7.62	0.38	0.69	1.49	1.79
SEm ±	0.38	0.06	0.02	0.03	0.01	0.04
CD(P=0.05)	0.92	NS	NS	0.06	0.02	0.09

Table 6 : Initial status of soil physical and physico-chemical properties at the time of sowing of maize (Mean of two years)

Treatments	Soil penetration resistance (SPR) (kg cm⁻²)	Soil pH	Electrical conductivity (dSm⁻¹)	Organic carbon (%)	Bulk density (Mg m⁻³)	Mean weight diameter(MWD) (mm) > 0.25 mm
Transplanted rice	45.8	7.61	0.38	0.63	1.50	1.75
Aerobic rice	41.7	7.55	0.36	0.67	1.46	1.79

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